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Invasive Species Working Group

Invasive Species Science Update

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IN THIS ISSUE

From the Editor

This newsletter is designed to keep managers and other users up-to-date with recently completed and ongoing research by RMRS scientists, as well as to highlight breaking news related to invasive species issues. The newsletter is produced by the RMRS Invasive Species Working Group (ISWG), a core group of scientists who volunteer to disseminate RMRS invasive species science to managers and the public through this newsletter, the website, and periodic white papers. All of our products, including past issues of the newsletters and lists of publications, can be found online at: www.fs.fed.us/rmrs/groups/invasive-species-working-group.

In this issue, we cover new research ranging from using chili powder to improve native plant restoration, searching for a link between exotic white pine blister rust and mountain pine beetle resistance in limber pine, identifying how melting arctic sea ice could open new pathways for invasive species introductions, and research into a relatively newly established biocontrol agent for rush skeletonweed. This issue also sees the return of a popular section called "Ask the Experts", and it addresses a question about the important topic of secondary weed invasion. As always, we welcome feedback on ways to improve the ISWG and this newsletter. If you have comments or questions, please contact the ISWG team leader, Justin Runyon, justin.runyon@usda.gov.

USDA Forest Service—RMRS

Figure 1. Releasing rush skeletonweed root moths in Idaho as part of a study examining effectiveness and redistribution of this relatively new biocontrol agent, see page 6 (photo by Justin Runyon, RMRS).

Spicing Up Restoration: Using Chili Powder to Reduce Seed Predation and Improve Restoration Seeding

By: Dean Pearson (dpearson@usda.gov) and Yvette Ortega (yortega@usda.gov), RMRS Forestry Sciences Laboratory, Missoula, Montana

Rodent seed predation represents a substantial but underappreciated cause of seed mortality in native plant restoration projects. Native deer mice are voracious seed predators common in many habitats that are targeted for restoration across Montana and North America. These mice have been shown to suppress recruitment of prominent large-seeded native plants that are important components of natural grasslands and integral to restoration seed mixes, including: bluebunch wheatgrass, lupine, arrowleaf balsamroot, and blanket flower, among others.

Recently, a team of researchers and managers lead by Rocky Mountain Research Station scientists demonstrated that applying chili powder to bluebunch wheatgrass and other native plant seeds could reduce rodent seed predation enough to substantially increase seedling recruitment. Even more, this approach reduced restoration costs because the increase in seedling recruitment was substantial enough to lower the cost per recruiting seedling for treated vs. untreated seeds, despite seed coating costs. The reason this trick works is that the active ingredient in chili powder, capsaicin, burns the mouths of mice the same as it does humans. In fact, this compound is believed to have evolved in peppers as a means of protecting their seeds from rodent seed predators. So if you get the pepper hot enough, the mice give up! This approach is an example of biomimicry—copying Mother Nature's tricks for human benefits—and it demonstrates how much we can learn from studying nature. While this study was a small scale proof-of-concept experiment, it is hoped that this new method can be perfected at larger industrial scales to improve native plant restoration.

Figure 2. Pepper-coated (left) and uncoated (right) bluebunch wheatgrass seeds ready for sowing (photo by Dean Pearson, RMRS).

Pearson, D.E.; Valliant, M.; Carlson, C.; Thelen, G.C.; Ortega, Y.K.; Orrock, J.L.; Madsen, M.D. 2019. Spicing up restoration: Can chili peppers improve reseeding success by reducing seed predation? Restoration Ecology. 27: 254-260. doi: 10.1111/rec.12862

Links to popular press

- *www.thesciencebreaker.org/breaks/plant-biology/spicing-up-restoration-can-a-dash-of-pepper-powder-defend-native-plants*
- *www.atlasobscura.com/articles/chili-peppers-stop-mice*
- *www.greenmatters.com/news/2018/08/07/Z1truT1/ghost-pepper-coating-seeds-grasslands*

Link to podcast

- *www.byuradio.org/episode/a337611e-f4bf-4e60-be59-204b4fdde721?playhead=4887&autoplay=true*

Relationship Between Resistance to White Pine Blister Rust and Mountain Pine Beetle

By: Anna Schoettle (anna.schoettle@usda.gov) and Christine Holtz (christine.t.holtz@gmail.com) RMRS Forestry Sciences Laboratory, Fort Collins, Colorado

Limber pine co-evolved with the native mountain pine beetle (MPB) and is now being threatened by the nonnative pathogen that causes the lethal disease white pine blister rust (WPBR). Previous research suggests that trees infected with WPBR can be preferred hosts for MPB. In their paper, "Is Resistance to Mountain Pine

Beetle Associated with Genetic Resistance to White Pine Blister Rust in Limber Pine?," RMRS Research Associate Christine Holtz and Research Plant Ecophysiologist Anna Schoettle tested for a relationship between resistance to MPB and WPBR in limber pine, in the absence of either biological agent, using resin duct traits. They were evaluating if MPB historically may have contributed to natural selection for WPBR resistance in advance of WPBR invasion, and could possibly explain the unusually high frequency of the dominant *Cr4* allele for complete resistance to WPBR in limber pine populations of the Southern Rocky Mountains. They found that MPB resistance does not appear to have played an evolutionary role in contributing to the high frequency of *Cr4* in naïve populations, however, MPB may affect the future evolution of resistance to WPBR in the pines where the two pests coincide and WPBR will affect forest recovery after MPB epidemics.

Figure 3. White pine blister rust on a limber pine twig (photo by Anna Schoettle, RMRS).

Holtz, C.T.; Schoettle, A.W. 2018. Is resistance to mountain pine beetle associated with genetic resistance to white pine blister rust in limber pine? Forests. 9(10): 595. doi: 10.3390/f9100595.

National Whitebark Pine Restoration Plan Effort

By: Anna Schoettle (anna.schoettle@usda.gov), RMRS Forestry Sciences Laboratory, Fort Collins, Colorado

A nonnative pathogen that causes white pine blister rust is threatening the high-elevation, five-needle whitebark pine. Bark beetles, past fire management, and climate change also threaten this species. In 2011, the U.S. Fish and Wildlife Service designated whitebark pine as a candidate species under the Endangered Species Act. The agency determined that the listing as "endangered" was "warranted but precluded" because of administrative backlogs, and the listing is currently under reevaluation. In Canada, the species is listed nationally as "endangered" under the Species at Risk Act.

The U.S. National Whitebark Pine Restoration Plan (NWPRP) effort is a collaboration among the USDA Forest Service, the Whitebark Pine Ecosystem Foundation, and American Forests. Central to the plan is the involvement of land management entities to identify core land areas for restoration. With the help of science syntheses, criteria development, and GIS data and tools, the land managers are to identify their whitebark pine land base, apply relevant criteria to prioritize areas for restoration/conservation, nominate 30 percent of the area (Core Areas) for active restoration/conservation, and propose restoration actions.

RMRS has long been a leader in whitebark pine research and is playing a role in the NWPRP effort. **Bob Keane**, Research Ecologist in Missoula, Montana, is on the development team and is in charge of compiling all the geospatial data gathered from the data calls and producing products to facilitate core area nominations and restoration action proposals. **Anna Schoettle**, Research Plant Ecophysiologist, is coordinating the data calls with both research and management as the FS R&D Liaison on the NWPRP Liaison Committee. The effort is expected to be completed by 2020.

FIgure 4. Restoration planting of a whitebark pine seedling (photo by Anna Schoettle, RMRS).

Figure 5. Field trip to discuss restoration strategies during the Whitebark Pine Ecosystem Foundation Annual Meeting in Idaho in 2018. Note the whitebark pine mortality (photo by Anna Schoettle, RMRS).

Melting Arctic Sea Ice and New Pathways for Invasive Species Introduction

By: Travis Warziniack (twwarziniack@usda.gov), RMRS Forestry Sciences Laboratory, Fort Collins, Colorado; Amanda Countryman (amanda.countryman@colostate.edu), Colorado State University, Fort Collins, Colorado; Duy Nong (duy.nong@colostate.edu), University of Bonn, Bonn, Germany; Erin Grey (egrey@govst.edu), Governor State University, Chicago, Illinois

The incidence of invasive species within the United States is closely linked with the Nation's history of settlement and economic trade. Nonindigenous species currently established in the eastern U.S. largely reflect long-standing ties with Europe, and nonindigenous species currently established in the western U.S. largely reflect trade patterns with Asia. The land mass of North America, to some degree, has helped maintain this separation. Things are changing, however, due to climate change, melting Artic sea ice, and the opening of navigable waters in the Arctic that connect Asia with the eastern U.S. and Europe. Two main routes are already seeing expanded use: the Northern Sea route and the Northwest Passage. The Northern Sea route reduces the marine distance between Northwest Europe and Northeast Asia by 40 percent, as compared to the passage through the Suez Canal. The Northwest Passage reduces the sailing distance between Northeast Asia and the U.S. Atlantic coast by about 25 percent, as compared to the Panama Canal route. The two Arctic lanes allow shipping companies to avoid increased tolls in the Suez and Panama Canals and are expected to make possible the navigation of super ships that are larger and able to carry greater volumes of cargo.

We looked at the impact that increased Arctic shipping will have on the global spread of nonindigenous species and threats to the U.S. by combining an economic trade model (the Global Trade Analysis Project, or GTAP, model) with a climate matching model, to identifying trade partners and commodities likely to pose the most risk. Risks associated with oceanic shipping come primarily from hitchhiking species on ship hulls (hull fouling), in ballast water, in cargo, and in packaging material and wooden crates. For the U.S., we find the greatest increase in relative risk of invasion comes from China, followed by Japan. Trade of all commodities represent risks to marine environments through ballast and hull fouling, but risk of introduction of terrestrial nonindigenous species varies considerably by the type of commodity shipped. We find that U.S. agricultural imports are expected to increase by 7 percent from Asia-Pacific trading partners. Imports of wood products are expected to increase by 8 percent from China and by 11 percent from the Philippines. Increased trade of these goods will bring increased occurrences of agricultural pests and forest and wood-boring insects.

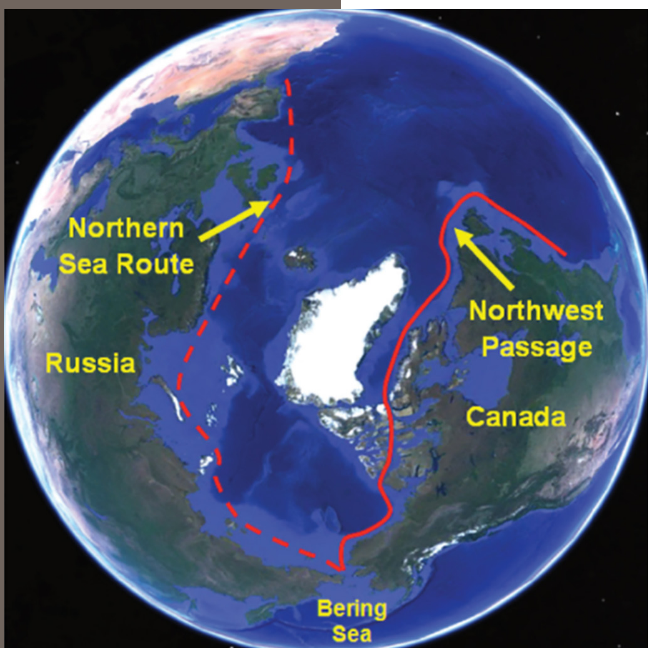

Figure 6. Map of the Arctic sea routes showing the Northern Sea Route along Russia's mainland and the Northwest Passage through the Canadian Arctic.

Our work not only provides information on the countries likely to present the most risk, it offers details of the type of goods that will harbor the next wave of invasive species. Sector-specific economic analysis linked to pest and pathogen profiles can go a step further to provide even greater detail on sources of risk. Such information can guide more focused trade policies and inspection protocols, and guide ballast treatment requirements for the new fleet of ships likely to traverse the Arctic.

Nong, D.; Countryman, A.M.; Warziniack, T.; Grey, E.K. 2019. Melting Arctic sea ice: Implications for nonindigenous species (NIS) spread in the United States. Environmental Science & Policy. 91: 81-91.

Nong, D.; Countryman, A.M.; Warziniack, T.; Grey, E.K. 2018. Arctic sea routes: Potential new pathways for nonindigenous species spread. Arctic. 71: 269-280.

Countryman, A.M.; Warziniack, T.; Grey, E. 2018. Implications for U.S. trade and nonindigenous species risk resulting from increased economic integration of the Asia-Pacific region. Society & Natural Resources. 31: 942-959.

Mogulones crucifer Science Advisory Panel set for April 30-May 1, 2019

By: Sharlene Sing (ssing@usda.gov), RMRS Forestry Sciences Laboratory, Bozeman, Montana

The Montana Invasive Species Council (MISC) will convene a Science Advisory Panel (SAP) April 30 through May 1, 2019, to scope the potential for permitted interstate movement and release of *Mogulones crucifer*, a weevil for classical biological control of houndstongue (*Cynoglossum officinale* L.) in the United States. The workshop will be held at Chico Hot Springs in Pray, Montana and is open to the public. The weevil, permitted for release in Canada in 1997 and well-established in Alberta and British Columbia, has migrated southward into Montana, Idaho, and Washington. *Mogulones crucifer* was not approved for release in the U.S. due to potential nontarget impacts on several native plant species. Encouraging results reported from recent graduate research projects addressing the candidate agent's host specificity suggest that adequate data now exist to support resubmission of a petition to release *M. crucifer* in the U.S.

Expected panel outcomes:

- Comprehensive review of studies assessing host specificity and nontarget impacts of *M. crucifer*, to determine if this new information adequately addresses historic reservations regarding the safety of *M. crucifer*.
- Determine if new information subsequent to the review of the original petition to release is substantive enough to trigger changes to *M. crucifer's* current pest status.
- Identify knowledge gaps and probable challenges associated with the approval for *M. crucifer* as a biocontrol agent in the U.S., and identify information/efforts that would address those gaps and challenges.
- Provide next steps to be taken by researchers, regulators and managers regarding the status of *M. crucifer*.
- Provide input and guidance to managers of private and governmental lands on interacting with *M. crucifer* if it is encountered in the field.

Panelists will include Dr. Robert S. Pfannenstiel, Entomologist, Pest Pathogens and Biocontrol Permitting, Plant Health Programs, USDA APHIS PPQ; Dr. Cindy Hall, National Coordinator, Integrated Pest Management, U.S. Fish and Wildlife Service; Dr. Mark Schwarzlander, Entomology, Plant Pathology and Nematology University of Idaho; Dr. Rosemarie De Clerck-Floate, Research Entomologist, Lethbridge Research and Development Centre Agriculture and Agri-Food Canada; Dr. Al Cofrancesco, Technical Director, Civil Works Environmental Engineering and Sciences, U.S. Army Engineer Research and Development Center, Vicksburg Mississippi, and Chair, Technical Advisory Group for Biological Control Agents of Weeds; Dr. Robert Nowierski, National Program Leader, Division of Plant Systems-Protection, USDA NIFA; and Ms. Jennifer Andreas, IWCP Director, Washington State University Extension. De Clerck-Floate, Schwarzlander and Andreas have all conducted and/or supervised research on the candidate agent.

RMRS Research Entomologist Sharlene E. Sing serves as the co-chair of the *Mogulones crucifer* SAP steering committee and as the USDA Forest Service representative on the Technical Advisory Group for Biological Control Agents of Weeds.

The Rush Skeletonweed Root Moth Newly Established in North America: Assessing Impact and Redistribution

By: Jeff Littlefield (jeffreyl@montana.edu), Department of Land Resources and Environmental Sciences, Montana State University; Justin Runyon (justin.runyon@usda.gov), RMRS Forestry Sciences Laboratory, Bozeman, Montana

Rush skeletonweed (*Chondrilla juncea,* RSW) is an invasive weed of Eurasian origin found throughout semiarid areas of the western United States. It is a long-lived perennial with an extensive root system that outcompetes and replaces native forbs and grasses. Some of the worst RSW infestations are in Idaho and eastern Washington (>4.5 million ac infested). Many different land types may be infested, including: roadsides, railways, rangelands, pastures, grain fields, and sandy hillsides in mountainous regions. Infestations of RSW continue to expand as much as 100,000 acres per year and it has recently spread to British Columbia, Montana, and Utah.

Scientists successfully introduced three biocontrol agents in the 1970s through a biological control program that included a rust, gall mite and gall midge. These agents, however, have had only limited suppression of RSW populations, depending upon location. A fourth agent, the rush skeletonweed root moth, *Bradyrrhoa gilveolella*, was initially released in 2001. This moth is native to Greece and Eastern

Figure 7. A rush skeletonweed root moth at research site in the Payette National Forest in Idaho (photo by Justin Runyon, RMRS).

Europe and is specific to RSW. Initially established at one site north of Boise, Idaho, it has since established at a few new sites in Idaho and Oregon.

Bradyrrhoa appears to have one generation per year, with adults emerging from late May to late August with peak emergence in early July. Females can lay up to 250 eggs onto stems or the soil surface near the bases of plants. Larval development and pupation take place entirely beneath the soil surface within a feeding tube that is attached to the root. The tube is made of loosely spun silk initially, but is later covered with latex, root fragments, frass, and soil. The moth overwinters as larvae within feeding tubes. Although we have observed plants with up to 12 larvae per root, there are typically 1-3 larvae per plant. Larvae do not feed deep into a root but may sever roots of small skeletonweed plants, killing them.

Figure 8. Collecting adult rush skeletonweed root moths in a large infestation of rush skeletonweed. Adults will be used for research and redistribution, but must be hand-collected one at a time (photo by Jeff Littlefield, Montana State University).

It can take 5 or more years after release to build detectable and sometimes large moth populations. However, at our primary study site in the Payette National Forest of Idaho, moth numbers have declined with time, perhaps due to dispersal or unknown factors. Dispersal of moths from established populations has been slow, whereas in Europe the moth is reported to be good disperser. Despite a decline in *Bradyrrhoa* numbers, we observed a decline in RSW density, cover, and plant size (i.e. root diameter), indicating a possible impact on the plant. Plant density has declined from 29 plants/ 0.25 m^2 in 2011 to just 7.0 plants in 2018. Preliminary analysis of data also indicated that feeding may be disproportionately affecting larger diameter RSW roots, leaving plants with smaller roots in general.

Redistribution of the moth to new sites has proven difficult. Adult moths are difficult to collect in large numbers using sweep nets or other collection methods (such as black light trapping); and therefore moths must be collected individually. Due to low numbers at field sites it is difficult to collect adequate numbers for movement to new sites. Also, establishment at redistribution sites has been poor. Previously, we have attempted to release 100-200 moths per site. Larger releases may help establishment since sex ratios of the root moth seem to favor males. This research is ongoing and has been supported in part by the Forest Service's Biological Control of Invasive Plants (BCIP) program.

Littlefield, J.L.; Markin, G.; Kashefi, J.; de Meij, A.; Runyon, J. 2013. The release and recovery of *Bradyrrhoa gilveolella* on rush skeletonweed in southern Idaho. In: Proceedings of the XIII International Symposium on Biological Control of Weeds; September 11-16, 2011. Waikoloa, Hawaii, USA .Wu, Y.; Johnson, T.; Sing, S.; Raghu, S.; Wheeler, G; Pratt, P.; Warner, K.; Center, T.; Goolsby, J.; Reardon, R. (eds.). p. 478-479. Online: www.fs.fed.us/rm/pubs_other/rmrs_2013_littlefield_j001.pdf

Conservation Through Biocontrol: The Yellow Toadflax Stem Galling Weevil *Rhinusa pilosa*

By: Sharlene Sing (ssing@usda.gov), RMRS Forestry Sciences Laboratory, Bozeman, Montana

RMRS research entomologist Sharlene Sing will make the first U.S. field releases of a new biocontrol agent for yellow toadflax (*Linaria vulgaris*) in 2019. That agent, the stem galling weevil *Rhinusa pilosa*, is genetically diverse but declining in numbers across its native range (Serbia, Sweden, Denmark, Russia, Romania, and Tajikstan). In fact, *Rhinusa pilosa* could be on the verge of extinction in its native range due to competitive pressures exerted by the inquiline weevil *Rhinusa eversmanni*. *Rhinusa eversmanni* lays its eggs into fully developed *R. pilosa* galls, which allows their larger and more rapidly developing offspring to outcompete for food and habitat resources, and eventually kill any resident *R. pilosa* larvae.

Figure 9. Stem galling weevil Rhinusa pilosa *on yellow toadflax (photo by Ivo Toševski).*

The ratio of *R. pilosa* to *R. eversmanni* adults emerging from galls in Serbia 2016-2018 fluctuated between 1:7 and 1:10, with up to 100 percent of induced galls at some sites used for larval development of *R. eversmanni*. The rapid decline in effective population size of *R. pilosa* has resulted in severe genetic bottlenecking. To make matters worse, the majority of individuals from many native range populations have been put into intensive conservation breeding programs. As a result, diminishing native range populations are further jeopardized by continuous inbreeding, leading to increasingly profound fitness depression. Reduced fitness affects the adaptability of local populations to environmental changes. These factors, along with minimal gene-flow within native range metapopulations, may ultimately lead to the extinction of *R. pilosa* from suitable native range habitat within 2 to 3 years.

Our overseas collaborators believe there is hope for saving *R. pilosa* from extinction and preserving its genetic diversity through a mass rearing program in North America. The primary threat to the survival and genetic diversity of *R. pilosa* in its native range, *R. eversmanni*, would not exert any competitive pressure here because it has not (yet) become established in North America. This, coupled with a strategic rearing and release program aimed at increasing the agent's genetic variation, will improve the odds of successful establishment, increase, spread and impact under a wide range of North American field conditions.

Weevils sourced from Europe are being propagated at the RMRS Bozeman Forestry Sciences Laboratory for strategic release on sites representing an ecological gradient across the Dakotas, Montana, Idaho, Utah, Washington and Oregon. Agents will be deployed in this manner to systematically identify best matches between agent genotype/haplotype and habitat type. RMRS-led research will contribute to a regional study encompassing western Canada, the northwestern U.S., and Colorado. This collaboration benefits North American partners by providing a highly host-specific biological control agent for an ecologically and phenotypically plastic target weed that is challenging and expensive to manage with conventional approaches such as herbicide. Implementing target-specific and sustainable biocontrol of yellow toadflax is particularly important given the vast expanses of formerly forested acres in the Intermountain West that were affected by this invasive species following recent forest fires.

Figure 10. Rhinusa pilosa *galls produced on yellow toadflax plants, Bozeman Forestry Sciences Laboratory, August 2018 (photo by Sharlene Sing, RMRS).*

Gassmann, A.; De Clerck-Floate, R.; Sing, S.; Toševski, I.; Mitrović, M.; Krstić, O. 2014. Biology and host specificity of *Rhinusa pilosa*, a recommended biological control agent of Linaria vulgaris. Biocontrol. 59: 473-483.

Toševski, I.; Krstić, O.; Jović, J.; Sing, S.; Turner, S.; De Clerck-Floate, R. 2018. *Rhinusa pilosa*: a case study of environmental bottleneck. XV International Symposium on Biological Control of Weeds, Engelberg, Switzerland August 26-31, 2018.

Ask the Expert

***Q**: I'm working to manage spotted knapweed and have heard about secondary invasion by other weeds. Should I be worried about this problem and how can I avoid it?*

A: Secondary invasion occurs when an increase in abundance of nontarget weeds follows control of a targeted invasive plant. RMRS scientists recently conducted a worldwide analysis and found that secondary invasion is surprisingly common and often prevents successful weed management. The first step is to determine if other exotics are present that could emerge as important secondary weeds. If so, choose a tool that is effective against both the target and potential secondary invader(s). If such a tool is not available, consider combining tools to control both primary and secondary weeds. If no complementary tools exist, then treatment may not be advisable. These guidelines for reducing secondary invasion are outlined in the figure below. A critical but often overlooked aspect of weed control is revegetation, which can prevent secondary invasions by filling the hole created by suppression of the primary weed. Unfortunately, revegetation attempts frequently fail, but research is ongoing to improve plant selection and seeding techniques.

These steps are not a guarantee against secondary invasion, but should reduce the likelihood of occurrence. To learn more, see:

Pearson, Dean E.; Ortega, Yvette K.; Runyon, Justin B.; Butler, Jack L. 2016. Secondary invasion: The bane of weed management. Biological Conservation. 197: 8-17.

If you have an "Ask the Expert" question, please submit to Justin Runyon (justin.runyon@usda.gov).

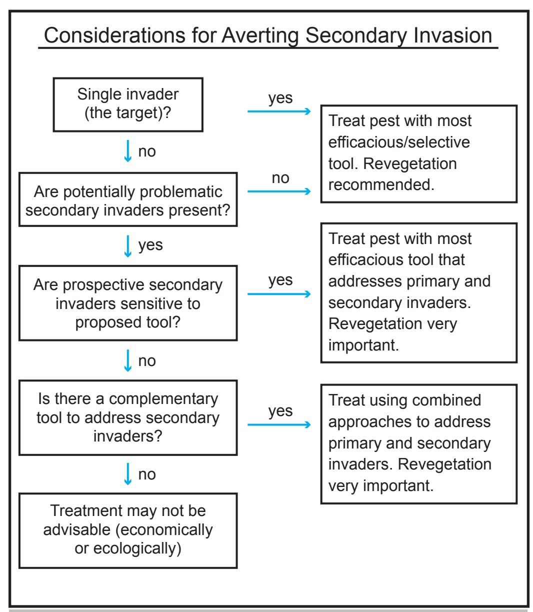

Figure 11. Guide to management actions for reducing the risk and severity of secondary weed invasion. This is not a guarantee against secondary invasion and is based on our incomplete understanding of this relatively newly recognized phenomenon (reproduced from Pearson et al., 2016).

Other News

Progar named National Lead for Entomology, Pathology, and Invasive Species

Dr. Robert Progar is now the National Lead for Entomology, Pathology, and Invasive Species Research in the Sustainable Forest Management Research Staff Area of Forest Service R&D. Rob is an entomologist with expertise in a variety of research areas including bark beetles, biocontrol of invasive plants, and pollinators. Rob has also taken the lead on communications and coordination in pollinator research in FS R&D. Welcome Rob!

Forest Service Roster of Invasive Species Experts is Updated

The USDA Forest Service has updated its Invasive Species Research Roster of Experts. This roster contains contact information, research interests, and current projects for more than 100 Forest Service scientists. If you would like a copy of this roster, please contact Rob Progar (robert.progar@usda.gov). This list will be updated periodically.

Conference: Genetics of Five-Needle Pines and Rusts, July 2019

The Second Joint International IUFRO Conference: Genetics of Five-Needle Pines and Rusts of Forest Trees will occur in Invermere, BC, Canada July 22-26 with an extended field trip opportunity July 26-30, 2019. This international meeting will address (1) Breeding and genetic conservation of five-needle pines, with special reference to screening and genetics programs for resistance to White Pine Blister rust (*Cronartium ribicola*) and (2) update the current state of knowledge of research in rusts. The first announcement can be found here: westernforestry.org/upcoming-conference-2nd-page/iufro-2019-joint-conference-genetics-of-five-needle-pines-rusts-of-forest-trees.

Other Recent Publications

Bennett. P.; Hill, J.; Savin, D.P.; Kegley, A.; Schoettle, A.W.; Sniezko, R.A.; Bird, B.; Stone, J. 2018. Genetic variation in stomate densities and needle traits in a range wide sampling of whitebark pine (*Pinus albicaulis*). In: Proceedings of the IUFRO joint conference: Genetics of five-needle pines, rusts of forest trees, and Strobusphere; 2014 June 15–20; Fort Collins, CO. 2018. Editors: Schoettle, A.W., R.A. Sniezko, J.T. Kliejunas. USDA For. Serv. Proc. RMRS-P-76. Pp 30-40.

Hunt, R.; Schoettle, A.W.; Chastagner, G. 2018. White pine blister rust. In: Hansen, E.M., K.J. Lewis, G.A. Chastagner (eds.). Compendium of Conifer Diseases, Second Edition. St. Paul, MN: American Phytopathological Society Press. p. 57-60.

Liu, J.J; Williams, H.; Li, X.R.; Schoettle, A.W.; Sniezko, R.A.; Murray, M.; Zamany, A.; Roke, G.; Chen, H. 2017. Profiling methyl jasmonate-responsive transcriptome for understanding induced systemic resistance in whitebark pine (*Pinus albicaulis*). Plant Molecular Biology. 95: 359-374. doi.org/10.1007/s11103-017-0655-z

Liu, J.J; Schoettle, A.W.; Sniezko, R.A.; Yao, F.; Zamany, A.; Williams, H.; Rancourt, B. 2019. Limber pine (*Pinus flexilis* James) genetic map constructed by exome-seq provides insight into the evolution of disease resistance and a genomic resource for genomics-based breeding. The Plant Journal. onlinelibrary.wiley.com/doi/full/10.1111/tpj.14270

Maron, J.L.; Hajek, K.; Hahn, P.; Pearson, D.E. 2018. Rodent seed predators and a dominant grass competitor affect coexistence of co-occurring forb species that vary in seed size. Journal of Ecology. 106: 1795-1805.

Miller, S.; Schoettle, A.W.; Burns, K.S.; Sniezko, R.A.; Champ, P. 2017. Preempting the pathogen: Blister rust and proactive management of high-elevation pines. USDA Forest Service, Rocky Mountain Research Station, Science You Can Use Bulletin No. 24. 11 p. www.fs.fed.us/rm/pubs_journals/2017/rmrs_2017_miller_s002.pdf

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Pearson, D.E.; Ortega, Y.K.; Eren, Ö.; Hierro, J.L. 2018. Community assembly theory as a conceptual framework for invasions. Trends in Ecology and Evolution. 33: 313-325.

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Pearson, D.E.; Ortega, Y.K.; Runyon, J.; Butler, J.L. 2018. Secondary invasion re-redefined: The distinction between invader-facilitated and invader-contingent invasions as subclasses of secondary invasion. Ecology and Evolution. 8: 5185-5187.

Schoettle, A.W.; Coop, J.D. 2017. Range-wide conservation of *Pinus aristata*: A genetic collection with ecological context for proactive management today and resources for tomorrow. New Forests. 48: 181-199. link.springer.com/article/10.1007/s11056-017-9570-z

Schoettle, A.W.; Jacobi, W.R.; Waring, K.M.; Burns, K.S. 2019. Regeneration for resilience framework to support regeneration decisions for species with populations at risk of extirpation by white pine blister rust. New Forests. 50: 89-114. doi.org/10.1007/s11056-018-9679-8.

Schoettle, A.W.; Burns, K.S.; Cleaver, C.M.; Connor, J.J. 2018. Proactive limber pine conservation strategy for the Greater Rocky Mountain National Park Area. Gen. Tech. Rep. RMRS-GTR-379. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 81 p.

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